**Method and device for identifying malfunctioning of a compressed air consumer circuit in an electronic compressed air system for a vehicle**

The invention relates to a method according to the preamble of claim 1 and to a device according to the preamble of claim 4 for detecting a failure of a compressed air consumer circuit in an electronic compressed air system for vehicles.

There are known multi-circuit protective valves that divide the energy supply into several mutually independent consumer circuits and that, in the event of failure of one consumer circuit, for example by line rupture, maintain a minimum pressure in the intact circuits. If a defect allowing more air to be lost than can be resupplied by the compressor occurs in a service-brake circuit, the pressure in the service-brake circuits drops mutually until the pressure reaches the closing pressure of the valve. The pressure in the defective circuit continues to drop, whereas the closing pressure is maintained in the intact circuit. While the pressure in the defective circuit continues to drop, the circuit that is still intact can be refilled by the compressor until the opening pressure of the defective circuit is reached. There is established a dynamic equilibrium, in which the delivered compressed air can supply the circuits that are still intact (as well as secondary consumer circuits), although at the same time air is being lost via the defect. During compressed air consumption of limited duration, as in the case of heavy

braking, there occur momentary dynamic pressure collapses, which do not correspond to the reservoir pressures of the individual consumer circuits. This behavior is much more pronounced in circuits without compressed air reservoirs than in circuits with compressed air reservoirs. A disadvantage of the known multi-circuit protective valves is that they react to such dynamic pressure collapses and shut off the circuit in question if the circuit in question has a low pressure level. The occurrence of such momentary dynamic pressure collapses therefore leads, at low pressure level, to premature shutoff of circuits, even though the respective pressure at the end of the event (of the pressure collapse) would still be higher than the closing pressure.

The object of the present invention is therefore to provide a method and a device of the type mentioned hereinabove such that premature shutoff of compressed air consumer circuits in response to brief dynamic pressure collapses is prevented.

Regarding the method, this object is achieved by the invention according to claim 1. A device for performing the method is specified in claim 4.

Advantageous and expedient improvements of the invention are specified in the dependent claims.

The invention proposes to measure a variable of state (pressure, air flow rate, air mass, energy) of the individual compressed air consumer circuits and to check whether the measured variable of state or possibly the negative gradient of the variable of state determined for a predefined time satisfies a circuit-failure criterion. The compressed air

consumer circuit in question is shut off only when this circuit-failure criterion is satisfied. By virtue of this inventive measure, premature shutoff of compressed air consumer circuits in response to brief dynamic pressure collapses is prevented, for example during intensive braking events. Thereby an increase of vehicle safety is achieved by improved energy supply to compressed air consumer circuits that already have a low pressure level due to air consumption. The inventive design ensures that compressed air consumer circuits that already have a low pressure level will be supplied with compressed air for a longer time.

The invention will be explained in more detail hereinafter on the basis of a practical example illustrated in the attached drawing, wherein:

Fig. 1 shows a block diagram of an inventive device and

Fig. 2 shows a diagram that illustrates the pressure variation over time during failure of a compressed air consumer circuit and during a plurality of successive compressed air consumptions of limited duration by the said circuit.

In the drawing, pressurized-fluid lines are represented by solid lines and electrical lines by broken lines.

The drawing shows a compressed air system 2 with a compressed air supply part 4 and a consumer part 6. Compressed air supply part 4 comprises a compressor 7, a compressor control device 8 and an air-dryer part 10.

Consumer part 6 is provided with a compressed air distributor line 14, a plurality of electrically actuatable valves, preferably solenoid valves 16, 18, 20, 22, 24 with restoring springs and a plurality of compressed air consumer circuits 26, 28, 30, 32, 34, 36, 38 supplied with compressed air via the solenoid valves.

From compressor 7, a compressed air supply line 40 leads via a filter 42, an air dryer 44 and a check valve 46 to distributor line 14, from which there are branched off lines 48, 50, 52, 54, 56 leading to the solenoid valves. From the solenoid valves, compressed air lines 58, 60, 62, 64, 66 lead to the consumer circuits. Line 62 splits into lines 62' and 62'' leading to circuits 30 and 32, a check valve 68 also being disposed in line 62''. A pressure limiter 70 is disposed in supply line 52. Line 54, which leads to solenoid valve 22, branches off downstream from pressure limiter 70. Line 64 splits into lines 64' and 64'' leading to circuits 34 and 36.

Pressure sensors 72, 74, 76, 78, 80, 82 monitor the pressure in the compressed air consumer circuits and in distributor line 14, and transmit the respective pressure as a pressure signal to electronic control unit 84, which controls the solenoid valves.

Compressed air consumer circuits 26, 28 can be, for example, service-brake circuits. Compressed air consumer circuit 30 can be a trailer-brake circuit, in which case normally two lines, a supply line and a brake line, lead to the trailer. Compressed air consumer circuit 32 can be a parking-brake circuit with spring accumulator. Compressed air consumer circuits 34 and 36 can be secondary consumer circuits, such

as operator's cab suspension, door controller, etc., in other words, all components that have nothing to do with the brake circuits. Compressed air consumer circuit 38 can be a high-pressure circuit.

Service-brake circuits 26, 28 are provided with compressed air reservoirs 90, 92 in conformity with EU Directive 98/12.

The inventive device or compressed air system makes it possible to dispense with compressed air reservoirs in circuits 30, 32, 34, 36 and also in high-pressure circuit 38. As an example, it is permissible to supply other compressed air consumer circuits from the service-brake circuits (circuits 26 and 28), provided the braking function or braking action of service-brake circuits 26 and 28 is not impaired.

Via a line 40', compressor 7 is mechanically (pneumatically) controlled by compressor controller 8. Compressor controller 8 comprises a solenoid valve 94 of small nominal width that can be switched by electronic control unit 84. In the de-energized normal state it is vented, as illustrated, whereby compressor 7 is turned on. If compressor 7 is to be turned off, for example because all compressed air consumer circuits are filled with compressed air, control unit 84 changes over solenoid valve 94 so that the pressure-actuatable compressor is turned off via line 40'. If solenoid valve 94 is switched to de-energized condition, for example because a compressed air consumer circuit needs compressed air, solenoid valve 94 is again switched to the normal state illustrated in the drawing, whereby line 40' is vented and compressor 7 is turned on.

Air-dryer part 10 comprises a solenoid valve 100 with small nominal width, whose inlet 102 is in communication with distributor line 14 and via whose outlet 104 there is pneumatically switched a shutoff valve 106, which is in communication with supply line 40 of compressor 7 and serves for venting of the air dryer.

When solenoid valve 100 is switched to passing condition, compressor 7 no longer discharges into the compressed air consumer circuits but instead discharges via valve 106 to the atmosphere. At the same time, dry air flows from distributor line 14 (out of reservoirs 90, 92 of the service-brake circuits) via solenoid valve 100, throttle 108 and a check valve 110 through air dryer 44 for regeneration of its desiccant and further via filter 42 and valve 106 to the atmosphere.

Reference numeral 112 denotes an overpressure valve.

Solenoid valves 16, 18, 20, 22, 24 are controlled by control unit 84, solenoid valves 16 to 22 of compressed air consumer circuits 26 to 34 being open in de-energized normal state, while solenoid valve 24 of the high-pressure circuit is closed in de-energized normal state. Pilot-controlled solenoid valves can also be used. The pressure in the circuits is directly monitored at the solenoid valves by pressure sensors 72, 74, 76, 78, 80.

By virtue of this inventive design, it is possible to do without pressure reservoirs in the consumer circuits (except in the service-brake circuits).

If the pressure were to drop in a compressed air consumer circuit, for example in circuit 30 (trailer-brake circuit), the compressed air supply also takes place by service-brake circuits 26 and 28, the pressure in compressed air consumer circuits 30 to 36 being adjusted by pressure limiter 70 to a lower level, such as 8.5 bar, than the pressure level of, for example, 10.5 bar in the service-brake circuit. High-pressure circuit 38 is shut off and therefore is not in communication with the other circuits. The high-pressure circuit usually has a higher pressure than the other compressed air consumer circuits, such as 12.5 bar.

In compressed air consumer circuits that already have a low pressure level due to air consumption, and in the case that conventional multi-circuit protective valves are used, the danger exists that, if dynamic pressure collapses of limited duration occur for operational reasons, such as during braking events, the compressed air consumer circuits in question will be immediately shut off, even though no defect due to line break or the like exists. In order to prevent this, it is provided according to the invention that electronic control unit 84 measures the pressures in the individual compressed air consumer circuits and/or determines negative pressure gradients and compares them with a respective predefinable lower threshold value S (see Fig. 2). The threshold value of pressure corresponds to the pressure to be adjusted in the respective compressed air consumer circuit. If the pressure drops below this threshold value, and/or if the negative pressure gradient decreases below a corresponding threshold value, this indicates a defect in the compressed air consumer circuit in question, due to line rupture, break or the like. In order to be certain whether this conclusion is correct, a test is performed to determine whether a circuit-failure criterion is satisfied. For this purpose the pressure

measurements are performed over a predefinable time t (see Fig. 2). The circuit-failure criterion is satisfied when the pressure values and/or pressure gradients are below the respective threshold value for a time t equal to or longer than the time $t_{dyn}$ of a dynamic pressure change or of a dynamic pressure collapse ($t \geq t_{dyn}$). Only if the results are below the threshold value S for a time $t \geq t_{dyn}$, therefore, is it definitively established that the compressed air consumer circuit in question is defective, $t_{dyn}$ being the time from the beginning to the end of a dynamic pressure collapse. The compressed air consumer circuit in question is then shut off. Hereby dynamic events caused by operational reasons are compensated for instead of leading to disadvantageous premature shutoff of the compressed air consumer circuit in question, as would otherwise be the case. The time $t_{dyn}$ is resident in the program of control unit 84 or is measured in real time. An example of a typical time for $t_{dyn}$ is 1 sec.

By means of curve 76 A, the diagram illustrated in Fig. 2 shows the pressure variation, for example in compressed air consumer circuit 30, during failure of that circuit. The pressure drops below the threshold value S at instant $t_1$ and is still below it at instant $t_2$, after a time $t \geq t_2 - t_1 \geq t_{dyn}$ has elapsed. Electronic control unit 84 then detects the fact that compressed air consumer circuit 30 has failed, and it shuts off the circuit by closing solenoid valve 20, since the circuit-failure criterion is satisfied.

Curve 76 B in Fig. 2 represents the pressure variation during several successive dynamic compressed air consumptions of limited duration. In the example according to Fig. 2, the pressure does not drop below the threshold value S until instant $t_3$, during the fifth dynamic compressed air consumption. At instant $t_4$, the pressure rises above the

threshold value once again, and thus the dynamic compressed air consumption is ended. Since the time $t = t_4 - t_3$ is $< t_{dyn}$, the circuit in question is not shut off, since the circuit-failure criterion is not met. Only during the following dynamic compressed air consumption, starting at instant $t_5$, does the pressure drop below the threshold value S for a time $t \geq t_6 - t_5 \geq t_{dyn}$. In this case the circuit-failure criterion is satisfied and the circuit in question is shut off.

As an alternative to the pressure, it is also possible to monitor other variables of state, such as air flow rate, air mass and energy, of the compressed air consumer circuits.